Coastal and Marine Sector Contribution to the National Assessment of the Potential Consequences of Climate Variability and Change for the United States

In 1997, the US Global Change Research Program (USGCRP) initiated an assessment of the significance of climate change for the United States. The goal of this National Assessment was to evaluate what is known about the potential consequences of climate variability and change in the context of other pressures on the public, the environment, and the Nation's resources. The Assessment drew on inputs from academia, government, the public and private sectors, and interested citizens. Starting with broad public concerns about the environment, the assessment explored the degree to which existing and future changes in climate might affect issues that people care most about. The National Assessment had three major components, reports of which are available at http://www.usgcrp.gov:

National Overview, written by thirteen prominent experts from academia, governmental, and non-governmental organizations, and based on studies completed by mid 2000. The team integrated findings from the regional and sectoral analyses and the broader literature, drawing conclusions about the importance of climate variability and change for the country as a whole. The National overview and foundation reports are available from Cambridge University Press (http://www.cup.org).

Regional Analyses, that characterized potential consequences of climate variability and change in selected US regions, focused on the interests of people in those regions.

Sectoral Analyses characterized potential climate consequences for five sectors: Agriculture, Forests, Human Health, Water, and Coastal Areas and Marine Resources. This assessment is available at http://cop.noaa.gov/pubs/das/das21.html and in "Climate Change Impacts on U.S. Coastal and Marine Ecosystems" (Scavia et al, 2002, Estuaries 25, in press). This report was prepared by the following tream:

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COASTAL AREAS and MARINE RESOURCES

The Potential Consequences of Climate Variability and Change

A Report of the National Coastal Assessment Group

For the U.S. Global Change Research Program

December 2001

Coastal Regions are Home to Half our People

The US has over 95,000 miles of coastline, ranging in habitat type from tropical coral reefs in American Samoa to the permafrost and ice-covered Arctic in northern Alaska, and from the rocky coasts of Maine and Oregon to the sandy beaches of Texas and Florida. Although only about 17% of the Nation's land lies within coastal counties, these lands are home to about 53% of our population—nearly 140,000,000 people. And more Americans visit these coastal areas each year for business, recreation, and aesthetic enjoyment.

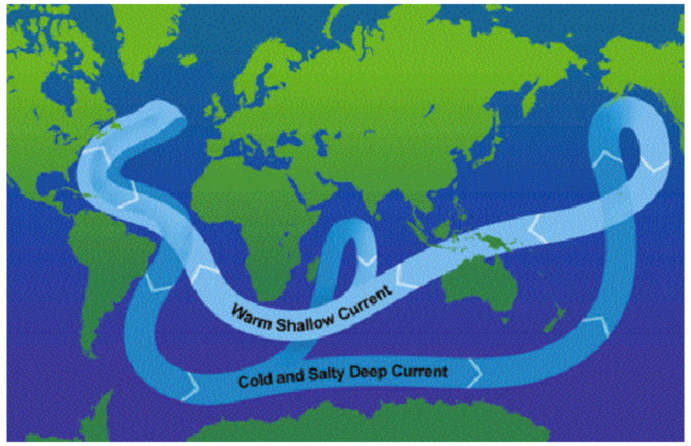
The US has approximately 3.4 million square miles of ocean and coastal waters within its boundaries, all of which provide society with many essential goods and services. These include commercial and recreational fisheries, shipping, aquaculture, mineral resources, sailing and other recreation, natural habitat for diverse plant and animal life, nutrient cycling, and protection from storms. Roughly one out of every six jobs in the US is coastal or marine related. Nearly 40% of the total value of US trade goes through US ports, and nearly one-third of the gross domestic product is produced in coastal areas.

The US coastal population is currently growing faster than the Nation as a whole, a trend that is projected to continue. Over the next 25 years, the coastal states of Florida, California, Texas, and Washington alone are expected to gain approximately 18 million people. This growth, along with rising wealth and affluence, is increasing the demand for coastal and marine resources, as well as increasing the stress on those resources and their vulnerability to climate change and variability.

This pamphlet summarizes the key findings of an assessment of how climate variability and change will affect:

- Coastal Communities
- Estuaries
- Coastal Wetlands
- Coral Reefs
- Marine Fisheries

Climate Change is Introducing an Important Additional Stress



The coastal and marine environment is linked to, and affected by, oceanic and climatic conditions. Sunlight, snow and rainfall patterns, freshwater runoff, sea surface temperatures, ocean currents, winds, storms, waves, tides, storm surges, and long-term sea level change influence the kinds of lands, habitats, and ecosystems found along the coast and in the nearby ocean. The abundance of critical resources and the ambiance that people enjoy are a direct result of how these forces shape the coastal environment. However, this environment also faces a wide array of human-induced stresses, including pollution, invasive species, the impacts of land and resource use, and climate change.

Human-induced climate change, caused by increasing greenhouse gas concentrations, increases natural climate variability, introduces additional coastal and marine pressures, and intensifies other existing stresses. These climate-change forces may be grouped into five categories:

Ocean Temperature and Sea Ice Extent: During the last half of the 20th Century, in some parts of the ocean, temperature increased and sea ice coverage was reduced as it melted. By the end of the 21st Century, sea surface temperatures at higher latitudes are projected to be much higher, and Arctic sea ice may be gone for most of the year.

Sea-Level Rise: While sea level has been rising gradually since the end of the last Ice Age, measurements during the 20th Century show that global sea-level rose about 4-8 inches, with melting glaciers and warming oceans playing important roles. For the 21st Century and beyond, global sea level rise is projected to be several times larger than during the 20th Century. However, local changes in land elevation cause considerable regional variation. Some West Coast lands are slowly rising, resulting in nearly no current increase in relative sea level. On the other hand, compaction of muddy soils and oil and water extraction are causing lands in parts of Louisiana and Texas to sink, resulting in current relative sea level rise of as much as 20-40 inches.

Ocean Currents and Dynamics: As global climate changes, changes in temperature and wind patterns could lead to more persistent El Niño-like conditions in the Pacific Ocean, including shifts in the California Current. Changes in Atlantic Ocean deep-water circulation could slow the Gulf Stream, with profound effects on both ocean and air temperatures in the North Atlantic region.

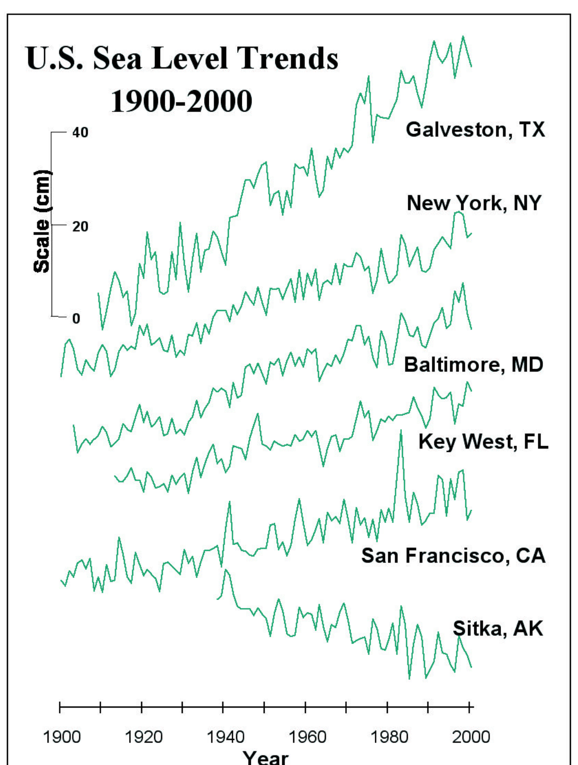
Coastal Storms: The number of hurricanes in a given year can vary widely, and large variations occur in their frequency and preferred paths. Therefore, it will take many years to decipher trends regarding how many hurricanes will occur in any season. Nonetheless, climate models suggest that warming will increase both wind speed and rainfall in the hurricanes that do develop. In addition, storm surges caused by these coastal storms will ride on higher water elevations due to a rise in sea level, and the erosion damage to coastal communities will be greatly exacerbated.

Freshwater Inflow from Land: Estuarine salinity and temperature depends on the amount and timing of river runoff and tidal flushing, and climate models project significant changes in both properties. While it is not clear whether precipitation changes will produce more or less rain in a given region, those changes, along with projected increases in extreme rainfall events, are likely to cause significant changes in the freshwater, chemical, and sediment load to estuaries and the coastal ocean.

Coastal Communities and Shoreline Erosion

Current Situation: Coastal erosion is a natural process. When development is placed too close to the shoreline, coastal erosion becomes a problem. Coastal erosion is already causing significant impacts on coastal buildings and infrastructure and along undeveloped shorelines. Coastal storms and hurricanes along the Louisiana, Texas, and Atlantic coasts cause severe erosion and multi-billion dollar losses, and the ability of coastal ecosystems, such as mangroves, to keep up with sea-level rise will be greatly undermined by coastal storms. Along the Pacific Coast, cycles of beach and cliff erosion have been linked to El Niño events which can alter storm tracks and raise sea level 4-8 inches over the short term.

Potential Consequences: Sea-level rise resulting from climate change is one of the most significant threats to shorelines because it increases the vulnerability of developed shorelines and low-lying areas by raising the baseline elevation level for extreme storms and coastal flooding events. The projected sea-level rise of about 1 to 3 feet during the 21st Century, with even higher levels to follow, would significantly increase stress on coastal transportation, public sanitation, recreation, and



industrial and housing facilities. The potential increase in the intensity of coastal storms and hurricanes which produce high winds, large waves, and significant storm surges, have the potential to cause even greater human and economic losses than these events do today. The large number of homes and communities built on barrier islands are particularly vulnerable. Efforts to protect against coastal erosion by constructing seawalls have adverse impacts of their own. For example, seawalls prevent the landward migration of beaches and coastal wetlands that would naturally occur during periods of rising sea level. The front of the beach or wetland, however, continues to migrate landward, resulting in the eventual loss of the entire beach or wetland. Rising sea level will also push saltwater into coastal aquifers and affect surface-water drinking supplies for millions of coastal residents.

Management, Adaptation, and Coping: Where the value of coastal development is low, retreat from the coastline is likely the most realistic choice. In more developed areas, if abandonment is too costly, traditional approaches for protecting homes and facilities – beach replenishment and seawalls, with their resulting loss of beaches and habitat – will be required. The US would need to spend many tens of billions of dollars for such protective measures over the 21st Century, in addition to the potential losses from stronger storms and hurricanes. Restoration and protection of coastal wetlands and barrier islands that have been compromised by human development are also important, as these coastal features serve as storm buffers for many coastal communities.

Threats to the Health of Estuaries

Current Situation: Estuaries are productive ecosystems that form when freshwater flows into seawater to create a brackish environment. At this intersection of land and ocean, these ecosystems provide valuable services to human societies. They are highly valued for their aesthetic beauty, waterfowl habitats, recreational sites, and fishery resources. However, coastal ecosystems are stressed. For example, nearly 40% of the area covered by the nation's estuaries is affected negatively by pollution or habitat degradation. Primarily because of non-point source nutrient pollution, 67% of US estuaries show significant signs of eutrophication, including oxygen starvation, overgrowth of algae, disrupted food webs, and harmful algal blooms. Over 3,500 beach advisories and closings occur each year in the United States, primarily due to storm-water runoff and sewage overflows.

Potential Consequences: Many aspects of climate change are expected to impact estuaries. Productivity may change as fish and waterfowl habitats are altered. For example, changes in the timing and amount of snow melt and runoff in the Sierra Nevada Mountains are likely to affect the seasonal variation and range of temperature and salinity in San Francisco Bay. Sea-level rise is likely to alter the wetlands of Chesapeake Bay, and decreases in summertime runoff and warmer Bay water temperatures will likely lead to greater water stratification and potentially worsen the stress of low oxygen levels. Rising sea level will likely push saltwater farther up the Hudson River and other major rivers. Warmer river temperatures

in the Pacific northwest, combined with changes in temperatures in the northern Pacific Ocean, are likely to disrupt critical salmon runs. Changing precipitation patterns in the greater Mississippi River basin are likely to increase the nutrient load to the Gulf of Mexico and exacerbating the stress of low oxygen in the Gulf.

The Mississippi River Basin, the source of nutrients causing the 6,000- to 7,000-square-mile "dead zone," or hypoxia in the Gulf of Mexico.

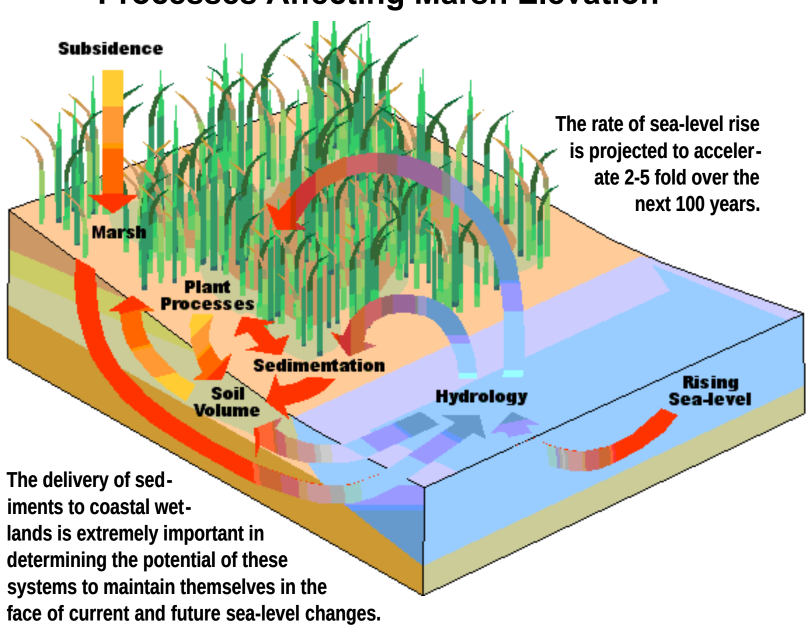
Management, Adaptation, and Coping: While restoration efforts are already under way for many degraded estuaries, few of these plans take into account the projected longer-term, climate-induced changes in temperature, precipitation, runoff, nutrient loads, and salinity. To limit the negative impacts of these projected climate-induced changes, managers will have to alter existing water-management and land-use policies, insisting for example, on more stringent nutrient management and more extensive restoration and protection of riparian zones and wetlands.

Loss of Coastal Wetlands and Habitats

Current Situation: While all coastal and ocean ecosystems are productive, the 15,000 square miles of coastal wetlands and the 2500 square miles of barrier islands in the eastern and southern US are of particular importance. The coastal wetlands, marshes, and mangrove forests in these low-lying areas are naturally flooded for much of the year. They serve as nurseries for juvenile fish, crustaceans, and mollusks, and are critical feeding areas and refuges for wildlife, fish, and invertebrates. Shallow ponds and seed-producing vegetation provide over-wintering habitat for millions of migratory waterfowl. Wetlands protect water quality by absorbing nutrients being carried to estuaries and the coastal ocean. They also protect coastal communities by damping river floods and ocean storm surges. Much of the current loss of US wetlands is caused by the combination of geologic processes, like land subsidence and compaction, and human development. Louisiana has been losing wetlands at the rate of between 24 and 40 square miles per year for the last 40 years, accounting for as much as 80% of total US coastal wetland loss.

Potential Consequences: If conditions are right, coastal marshes can survive rising sea levels. To do so, they must accumulate and build soil at the same rate as the water level is rising and/or the land is sinking, or they must migrate inland as areas that were once dry become flooded. Very often, however, the natural processes that enable wetlands to migrate are impaired by human changes in the coastal zone. Roads, canals, and dams on rivers can all change the way water and sediment move through these wetlands and sustain them, and can block their onshore migration. In these cases, coastal wetland loss is likely to be serious. In areas like Louisiana, where accelerated sea-level rise adds another stress to the already subsiding and massively altered marshes, losses could be even greater than at present. On other coasts, if coastal development is limited or if ecological reserves provide protection, wetlands will likely survive the pressures of sea-level rise by moving inland or rebuilding quickly enough to keep pace. However, without limiting development or increasing reserve areas, increased wetland losses in these areas may be widespread.

Processes Affecting Marsh Elevation

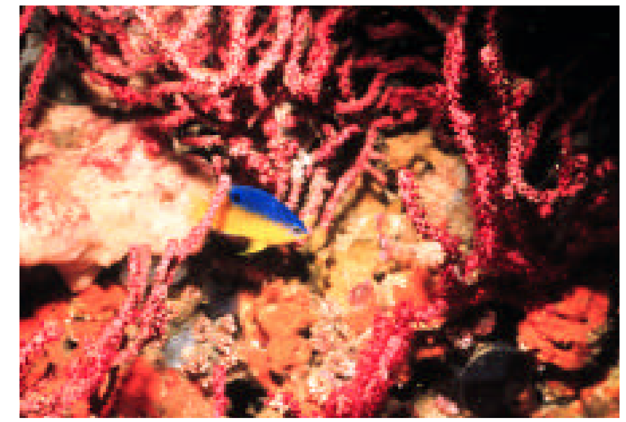


Management, Adaptation, and Coping: The key to coastal wetland survival is maintaining natural flows of water and sediment and allowing space for inland migration. Strategies to deal with the threats posed by climate change must address local conditions, and should also consider setting aside areas to allow inland migration, altering river controls (such as dams) to allow more sediment to reach the coast, and/or removing or modifying barriers like roads, railway embankments, seawalls, and other shoreline structures that change the natural patterns of flood and ebb of the tide and prohibit inland migration.

Coral Reef Die-offs

Current Situation: Coral reefs play major roles in the environment and economies of Florida, Hawaii, and most US territories in the Caribbean and Pacific. Coral reefs support fisheries, recreation, tourism, and coastal protection, and are one of the largest global storehouses of marine biodiversity and untapped genetic resources. Unprecedented declines in coral reefs have ocurred in the last few years as a result of very warm ocean temperatures, polluted runoff, and disease.

Potential Consequences: Higher ocean temperatures are expected to increase coral bleaching because the projected warming trends are similar to what occurred during the recent El Niño events that caused severe widespread bleaching. Increased atmospheric carbon dioxide levels are expected to lead to reduced coral calcification, making it more difficult for the coral growth needed to recover from storms and other events. Some estimates of the direct economic cost of coral reef loss are in the hundreds of billions of dollars, worldwide.



Management, Adaptation, and Coping: Coral reefs are generally stress-adapted, and disturbances play a key role in sustaining their high biodiversity. Because of this, when damaged by episodic events, they generally do recover. However, long-term climate-induced stresses will lead to sustained severe damage, from which recovery is also unlikely. The relocation of corals to higher latitudes in response to warmer temperatures is also unlikely because of chemical limitations caused by increased carbon dioxide levels. To help reef communities cope, other stresses, such as pollution and overfishing, must be reduced.

Stresses on Marine Fisheries

Current Situation: US commercial landings from marine fisheries yielded about $3.5 billion in 1999, with an estimated value-added contribution of $27 billion to the US economy. Recreational fisheries also add substantially to the economies and character of coastal communities. Climate variability has been shown to dramatically affect both the short- and long-term productivity of marine fisheries, and the combined effects of altered productivity and overfishing have led to numerous declines and collapses both in the US and world-wide.

Potential Consequences: Altered temperature, salinity, precipitation, wind patterns, and sea level will affect the distribution and abundance of marine organisms and impact commercial and recreational fisheries. Ocean warming is expected to cause poleward shifts in the ranges of tropical and lower-latitude organisms; these shifts may have significant secondary effects on the distributions and interactions of their predators and prey. For example, in the Northeast, cod, American plaice, haddock, Atlantic halibut, redfish, and yellowtail flounder are likely to move northward. Mid-Atlantic species, such as butterfish and menhaden, will likely extend into the Gulf of Maine. By the end of the 21st Century, ocean warming may render the North Pacific Ocean uninhabitable for sockeye salmon, restricting this species to the Bering Sea and the Sea of Okhotsk. These changes can ripple through marine ecosystems, impacting other sea life, from turtles to walrus.

Management, Adaptation, and Coping: Even without global climate change, many fisheries worldwide are under stress and at risk of collapse unless we adopt a more precautionary management approach. To cope with the additional stressors associated with climate-induced variability and change, both harvest rates and environmental change will have to be considered when developing and evaluating long-term management strategies and estimating sustainable yields.